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SUBJECT: Forwards projected values of pressurized thermal shock ref temps for reactor vessel beltline matls, per requirements of 10CFR50.61. No matls projected to exceed criteris of 10CFR50.61(b)(2).

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WISCONSIN PUBLIC SERVICE CORPORATION

January 23, 1986

Director of Nuclear Reactor Regulation
Attention: Mr. G. E. Lear, PWR Project Directorate-1
Operating Reactors Branch No. 1
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
TAC #M59960
Projected Values of RT_{PTS} as Required by 10 CFR 50.61

On July 23, 1985, 10 CFR 50.61, "Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events," became effective. Part (b)(1) of this rule required all pressurized water reactor licensees to submit projected values of RT_{PTS} for reactor vessel beltline materials by January 23, 1986. This submittal fulfills that requirement.

The attachment to this letter provides the projected values of RT_{PTS} along with the bases for the projection. Bases are provided for the definition of beltline materials, the selection of initial and margin values for RT_{PTS}, the selection of best estimate material properties, and the selection of best estimate fluence projections including assumptions regarding core loading patterns.

As is shown in Table I-1 of the attachment, none of the Kewaunee Nuclear Power Plant's (KNPP) reactor vessel beltline materials are projected to exceed the screening criteria established by 10 CFR 50.61(b)(2). Therefore, the analysis and submittal required by part (b)(3) of the rule do not apply to the KNPP.

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However, the RT_{PTS} projection will continue to be updated whenever changes in core loadings, surveillance measurements, or other information indicate a significant change in projected values. This fulfills the requirements of 10 CFR 50.61 for the KNPP. Should any questions arise during your review of this submittal, please feel free to contact my staff.

Sincerely,

D. C. Hintz
Manager - Nuclear Power

KAH/jms

Attach.

cc - Mr. Robert Nelson, US NRC

Attachment

To

Letter from D. C. Hintz (WPSC) to G. E. Lear (NRC)

Dated

January 23, 1986

Projected Values of RT_{PTS} as Required by 10 CFR 50.61

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LIST OF TABLES

REFERENCES

1) Letter from E. W. James (WPSC) to E. Case (NRC) dated July 8, 1977

2) Letter from E. R. Mathews (WPSC) to D. G. Eisenhut (NRC) dated August 7, 1981

3) Letter from R. L. Kelly (W) to C. W. Giesler (WPSC) dated January 16, 1978 (Letter number WPS-78-502)

4) Letter from R. A. Licciardo (NRC) to E. R. Mathews (WPSC) dated April 21, 1982

SECTION I

Projected Values of RT_{PTS}

Part (b)(1) of 10 CFR 50.61 requires the calculation of RT_{PTS} for reactor vessel beltline materials at the time of this submittal and the projection of RT_{PTS} for the same materials at the expiration date of the operating license. The date of this submittal is January 23, 1986 and the expiration date of the Kewaunee Nuclear Power Plant's (KNPP) operating license is August 6, 2008. To calculate the value of RT_{PTS} for these dates requires information concerning the identification of reactor vessel beltline materials, the initial value of reference temperature, the amount of margin necessary, the best estimate chemical properties of the material, and the best estimate neutron fluence. The basis for the values determined for these items is supplied in sections two through five.

The actual calculation of RT_{PTS} requires the use of two separate formulas specified by 10 CFR 50.61(b)(2). For each material, RT_{PTS} is the lower of the two results given by the equations. The equations are as follows:

Equation (1): $RT_{PTS} = I + M + (-10 + 470\ Cu + 350\ CuNi)f^{0.270}$

Equation (2): $RT_{PTS} = I + M + 283f^{0.194}$

where I = initial reference temperature (°F)
M = margin (°F)
Cu = best estimate weight percent of copper
Ni = best estimate weight percent of nickel
f = best estimate neutron fluence (10^{19} n/cm^2)

The following pages summarize the calculation of RT_{PTS} for the reactor vessel beltline materials. The results are tabulated in Table I-1. As this table shows, the projected values of RT_{PTS} do not exceed the screening criteria of 270°F for forgings or 300°F for circumferential weld materials.

Intermediate Shell Forging

Equation (1)

I = 60°F (Table III-1)
M = 48°F (Table III-1)
Cu = 0.06 w/o (Table IV-1)
Ni = 0.71 w/o (Table IV-1)
f = 1.25 x 10^{19} $^{n}/cm^{2}$ for January 23, 1986 (Table V-1)
f = 3.80 x 10^{19} $^{n}/cm^{2}$ for August 6, 2008 (Table V-1)

$RT_{PTS(1)}$ = 138°F on January 23, 1986
$RT_{PTS(1)}$ = 155°F on August 6, 2008

Equation (2)

I = 60°F (Table III-1)
M = 0°F (Table III-1)
f = 1.25 x 10^{19} $^{n}/cm^{2}$ for January 23, 1986 (Table V-1)
f = 3.80 x 10^{19} $^{n}/cm^{2}$ for August 6, 2008 (Table V-1)

$RT_{PTS(2)}$ = 356°F on January 23, 1986
$RT_{PTS(2)}$ = 427°F on August 6, 2008

RT_{PTS} = $RT_{PTS(1)}$ for both dates.

Lower Shell Forging

Equation (1)

I = 20°F (Table III-1)
M = 48°F (Table III-1)
Cu = 0.06 w/o (Table IV-1)
Ni = 0.75 w/o (Table IV-1)
f = 1.25 x 10^{19} $^{n}/cm^{2}$ for January 23, 1986 (Table V-1)
f = 3.80 x 10^{19} $^{n}/cm^{2}$ for August 6, 2008 (Table V-1)

$RT_{PTS(1)}$ = 104°F on January 23, 1986
$RT_{PTS(1)}$ = 117°F on August 6, 2008

Equation (2)

I = 20°F (Table III-1)
M = 0°F (Table III-1)
f = 1.25 x 10^{19} $^{n}/cm^{2}$ for January 23, 1986 (Table V-1)
f = 3.80 x 10^{19} $^{n}/cm^{2}$ for August 6, 2008 (Table V-1)

$RT_{PTS(2)}$ = 316°F on January 23, 1986
$RT_{PTS(2)}$ = 387°F on August 6, 2008

RT_{PTS} = $RT_{PTS(1)}$ for both dates.

Beltline Circumferential Weld

Equation (1)

I = -56°F (Table III-1)
M = 59°F (Table III-1)
Cu = 0.24 w/o (Table IV-1)
Ni = 0.78 w/o (Table IV-1)
f = 1.25 x 10^{19} $^n/cm^2$ for January 23, 1986 (Table V-1)
f = 3.80 x 10^{19} $^n/cm^2$ for August 6, 2008 (Table V-1)

$RT_{PTS(1)}$ = 182°F on January 23, 1986
$RT_{PTS(1)}$ = 244°F on August 6, 2008

Equation (2)

I = -56°F (Table III-1)
M = 34°F (Table III-1)
f = 1.25 x 10^{19} $^n/cm^2$ for January 23, 1986 (Table V-1)
f = 3.80 x 10^{19} $^n/cm^2$ for August 6, 2008 (Table V-1)

$RT_{PTS(2)}$ = 274°F on January 23, 1986
$RT_{PTS(2)}$ = 345°F on August 6, 2008

RT_{PTS} = $RT_{PTS(1)}$ for both dates.

Table I-1

Projected Values of RT_{PTS}

Material	RT_{PTS} January 23, 1986	RT_{PTS} August 6, 2008	Screening Criteria
Intermediate Shell Forging	138°F	155°F	270°F
Lower Shell Forging	104°F	117°F	270°F
Beltline Circumferential Weld	182°F	244°F	300°F

SECTION II

Definition of KNPP Reactor Vessel Beltline Materials

The reactor vessel beltline is defined by 10 CFR 50.61(a)(3) as "the region of the reactor vessel (shell material including welds, heat affected zones, and plates or forgings) that directly surrounds the effective height of the active core and adjacent regions of the reactor vessel that are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage."

For the KNPP reactor vessel, the intermediate shell forging, the lower shell forging, and the circumferential weld connecting these two forgings directly surround the active portion of the reactor core. There are no longitudinal welds. Of the reactor vessel beltline materials listed above, the circumferential weld is by far the most limiting material with regard to radiation damage due to the relatively high copper content of the weld as compared to the copper content of the forgings. In addition, no adjacent regions are predicted to experience sufficient neutron radiation damage to be considered in the selection of the most limiting material with regard to radiation damage. This is consistent with the items identified as potentially limiting materials by the KNPP vessel surveillance program. The results of this surveillance, along with a description of the program, have been provided to the NRC by references 1 and 2.

SECTION III

Basis for Initial and Margin Values for RT_{PTS}

The initial reference temperature of the unirradiated material is defined by paragraph NB-2331 of the ASME code edition and addenda specified by 10 CFR 50.55a. However, 10 CFR 50.61(b)(2)(i) allows specific generic mean values to be used if a measured value is not available. The margin to be added to cover uncertainties in the values of initial RT_{NDT}, copper and nickel content, fluence, and calculational procedures is dependent on whether the initial reference temperature is a measured value. Part (b)(2)(ii) of the rule specifies the margin to be added for each of the RT_{PTS} equations. The margin varies based on whether a generic mean or a measured value of initial reference temperature is used.

Intermediate and Lower Shell Forgings

The initial reference temperatures for the intermediate and lower shell forgings were measured in a manner that agrees with the current requirements of NB-2331. This measurement process was described in Appendix A of WCAP 8908, "Analysis of Capsule V from the Wisconsin Public Service Corporation Kewaunee Nuclear Power Plant Reactor Vessel Radiation Surveillance Program." This report was transmitted to the NRC by reference 1. The values of the initial reference temperature and the applicable margin are presented in Table III-1.

Beltline Circunferential Weld

The KNPP reactor vessel beltline circumferential weld was completed in 1970. At this time, the ASME code did not require the drop weight and Charpy tests that are necessary to determine the initial reference temperature in accordance with the current NB-2331. Therefore, the initial reference temperature for this weld must be estimated as allowed by 10 CFR 50.61(b)(2)(i). The initial value assumed is dependent on the weld flux used in the weld. As established by the NSSS vendor for the KNPP (reference 3), the weld flux used in the beltline circumferential weld was Linde 1092. The applicable values of initial reference temperature and margin are presented in Table III-1.

Table III-1

Initial Reference Temperatures and Margins

Material	Initial		Margin	
	Value	Measured or Generic	Equation 1	Equation 2
Intermediate Shell Forging	60°F	Measured	48°F	0°F
Lower Shell Forging	20°F	Measured	48°F	0°F
Beltline Circumferential Weld	-56°F	Generic	59°F	34°F

SECTION IV

Basis for Best Estimate Material Properties

Part (b)(2)(iii) of 10 CFR 50.61 requires the best estimate weight percent of copper and nickel to be used in the calculation of RT_{PTS} for the beltline materials. Also, the source of these values, along with the relationship of these values to the actual materials in the vessel, must be described.

Intermediate and Lower Shell Forgings

As part of the KNPP reactor vessel surveillance program, the KNPP vessel manufacturer provided sections of material that had been removed from the intermediate and lower shell forgings. These sections were then chemically analyzed. The results were supplied to the NRC in reference 1 as Table 4-1 of WCAP 8908. Therefore, the material chemically analyzed is directly related to the actual materials in the vessel. The chemical properties necessary for the calculation of RT_{PTS} are presented in Table IV-1.

Beltline Circumferential Weld

Along with the sections of the forgings described above, the KNPP vessel manufacturer also supplied a weldment made from pieces of the forgings using the same weld wire heat number and flux type as used in the actual vessel weld. This weldment was chemically analyzed and found to contain 0.20 weight percent (w/o) copper.

However, as more information concerning vessel welds began to circulate the nuclear industry, WPSC began to investigate the basis for using 0.20 w/o copper as a best estimate of the chemistry of the vessel weld. The initial information we received indicated that the copper content of the weld wire was not tightly controlled and could vary significantly. In fact, the value of 0.20 w/o copper was questioned by the NRC in the safety evaluation of the most recent revision to the KNPP heatup and cooldown limit curves (reference 4). The NRC safety evaluation apparently used a value of 0.24 w/o copper to provide additional assurance that our curves met the requirements of Regulatory Guide 1.99 Revision 1. This value of copper (0.24) was the minimum weld copper content that had been reported for twelve other vessels made by the KNPP vessel manufacturer.

With this preliminary information in hand, WPSC began an extensive investigation and document search involving the vessel manufacturer, the weld wire manufacturer, the Westinghouse Owners Group, and numerous other utilities. The investigation turned up complete information on three (3) data points from welds made with the same weld wire heat number as that used in the KNPP vessel weld and seventeen (17) additional analyses of other weld wire supplied by our weld wire manufacturer during the time period in which the KNPP vessel was fabricated.

The copper contents established by these analyses varied significantly, verifying the randomness of the copper coating process. For the three data points discovered for the weld wire heat number used in the KNPP vessel, the weld copper contents varied from 0.20 w/o to 0.385 w/o. Therefore, WPSC investigated further the actual process used to copper coat the weld wires.

The weld wire manufacturer informed WPSC that the weld wires were copper coated in order to prevent corrosion and therefore prolong the shelf life of the weld wire. In addition, the copper coating provided lubrication during the drawing process and increased the weld wire's electrical conductivity. At the time of the fabrication of the KNPP vessel, the weld wire manufacturer would copper coat all weld wires in the same manner, independent of the weld wire heat number and the initial copper content of the bare wire. Therefore, the following conclusions can be made:

1. The randomness of the process of adding copper to bare weld wire is the cause of the wide variance of final weld copper contents.

2. The amount of copper added to the wire is a process independent of the weld wire heat number.

To establish a best estimate value of the copper content of the KNPP vessel weld, the total of twenty data points applicable to our weld wire manufacturer were analyzed. Each of these data points had a final weld copper content and an initial bare wire copper content. This enabled the establishment of a data base consisting of the amount of copper added to various weld wires by the same manufacturer over a relatively short time frame using the same process. The twenty values were averaged, providing a mean value of 0.16 w/o copper added by the copper coating process.

For the weld wire heat number used in the KNPP vessel weld, a chemical analysis with the copper coating not present established a bare wire copper content of 0.08 w/o. This chemical value, along with the other chemical values of molybdenum, nickel, etc., is a very stable value due to the tight chemical controls and specifications concerning the manufacture of the bare wire. Unfortunately, the copper addition process was not as tightly controlled. Therefore, the best estimate of the copper content for the KNPP vessel beltline circumferential weld is the initial copper content of the bare wire plus the mean value of the copper added by the copper coating process. This results in a best estimate of 0.24 w/o copper.

As discussed by SECY 82-465, the RT_{PTS} screening values include a two sigma measure of error added to the mean. One reason for this large addition to the screening values was to cover any uncertainties introduced by the use of best estimate copper contents. Therefore, the use of a technically based best estimate copper content of 0.24 w/o is justified.

As mentioned earlier, nickel was one of the elements tightly controlled by the weld wire manufacturer when fabricating the bare wire for a specific heat number. Therefore, the best estimate of the nickel content of the KNPP reactor vessel is the mean of the three data points directly applicable to the heat number of the weld wire used in the vessel. This amount of nickel did not change as a result of the variable copper addition process. The chemical properties necessary for the calculation of RT_{PTS} are summarized in Table IV-1.

Table IV-1

Best Estimate Material Properties

Material	Copper	Nickel
Intermediate Shell Forging	0.06 w/o	0.71 w/o
Lower Shell Forging	0.06 w/o	0.75 w/o
Beltline Circumferential Weld	0.24 w/o	0.78 w/o

SECTION V

Basis for Best Estimate Fluence Projections

The fluence used to calculate RT_{PTS} is the best estimate fluence (energies greater than or equal to 1 MeV) at the clad-base metal interface on the inner surface of the reactor vessel. The fluence used is the maximum fluence received by the material for the time in question.

To assess the fluence accumulated by the KNPP reactor vessel, the power history of the reactor along with the fluence measured by two surveillance capsules was provided to a consultant. With this plant-specific data, the consultant used the DOT-IV Discrete Ordinates S_N Transport Code to calculate the peak inner diameter fluence accumulated by the vessel. The 47-group Bugle-80 neutron cross section library (based on the Evaluated Nuclear Data File ENDF/B -IV (1)), a P_3 expansion of the scattering matrix, and an S_8 order of angular quadrature were employed in this analysis. The peak inner diameter fluence was assumed to be located at the position of all the vessel beltline materials. No credit was taken for the variation of the fluence in the axial (z) direction.

One of the items investigated by the consultant was the relationship between peak inner diameter fluence and effective full power years (EFPY) of operation. Establishing this relationship between fluence and EFPY required the development of a plant specific core power distribution. This power distribution was obtained on a core location basis by averaging fuel assembly powers from all of the eleven cycles of operation. This average core power distribution included two cycles of operation without a low leakage core loading pattern as WPSC began using the low leakage pattern in cycle three. Therefore, the use of the average core power distribution to project future fluence is inherently conservative because future core loading patterns will continue to be low leakage patterns and the projected fluence assumes an average core loading pattern that is biased by the input of two cycles of an out-in core loading pattern.

As a result of the consultant's analysis, a relationship between peak inner diameter fluence and EFPY was established. Part (b)(1) of 10 CFR 50.61 requires projection of RT_{PTS} for the time of the submittal and the expiration date of the operating license. To establish the fluence at these dates using the data supplied by the consultant, the EFPY of operation had to be calculated. For projecting the EFPY for August 6, 2008, it was assumed that future capacity factors would remain consistent with the high values of recent cycles. This provides a best estimate of EFPY and fluence that is consistent with the projections of the WPSC fuel services group which is responsible for the core design of the KNPP. The best estimate fluence required for the calculation of RT_{PTS} is provided in Table V-1.

Table V-1

Best Estimate Fluence Projections

Date	Peak Inner Diameter Fluence (E $\geq$1 MeV)
January 23, 1986	1.25×10^{19} n/cm^2
August 6, 2008	3.80×10^{19} n/cm^2